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Developing Fill-Tube Ignition Targets for the National Ignition Facility (NIF)

NIF ignition targets are cryogenic to allow the formation of a smooth and uniform solid fuel layer inside an implosion capsule. The systems to fill targets by high-pressure diffusion are complex. We are investigating a simpler concept in which target assemblies and capsules with micron-scale fill holes are fitted with micro-fill tubes connected to a small, integral low-pressure fill reservoir (Fig. 1). These fill-tube targets would be mounted on a support cryostat at room temperature and, upon cooling, the fuel fill would condense into the capsule in a controlled manner.

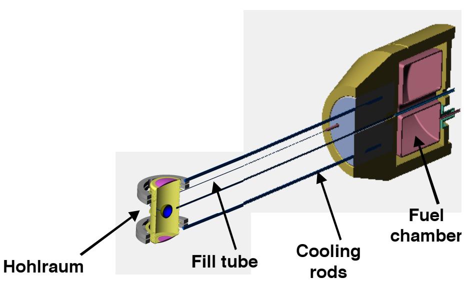

Fig. 1. Schematic of an ignition target that automatically fills itself upon being cooled to cryogenic temperatures.

A key to developing these ignition targets is demonstrating that the capsule fill holes can be made sufficiently small (a few microns in diameter) that they do not impact the spherically symmetric implosion leading to ignition. We must also demonstrate that the fuel volume can be controlled to better than one percent. We have made recent strides in both of these requirements.

Figure 2 shows an entrance and exit hole from an experiment in which we drilled 2-3-µm holes in 125-µm-thick Be foil. A short-pulse Ti:Sapphire laser delivered 10 mJ of 400-nm light in

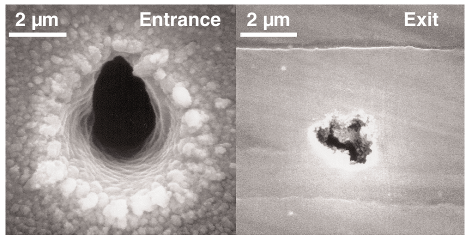

Fig. 2. Example of laser-drilled entrance and exit holes through a 125-µm Be foil.

a 110-fs duration pulse needed for the high-aspect-ratio holes. It is thought that the extremely high aspect ratios are made possible by the nature of the hole itself. As the hole begins to form, the walls of that hole become a metallic waveguide. This waveguide confines the propagating light in much the same way as an optical fiber, thereby overcoming the limited depth of focus created by the high numerical aperture focus lens. The short pulses are necessary to deliver sufficient peak power to ablate the material at the bottom of the hole with enough energy to allow the material to escape out the top. We have drilled holes in 20-30-µm-thick Be shells and plan to drill thicker shells this summer. In addition to providing a means of filling the otherwise impermeable shells, the holes also provide a means of removing the plastic mandrel on which the Be is coated. This is accomplished by placing the shell in a 450°C furnace and forcing hot air in and out of the shell by varying the furnace pressure. The hot air oxidizes the plastic to CO_2 and H_2O.

We have demonstrated controlled fuel filling of a NIF ignition capsule through a fill tube to better than one percent using a target assembly like that in Fig. 1., with a self-contained fuel reservoir connected to a capsule mounted in a NIF-scale hohlraum. An 8-µm ID fill tube is attached to the capsule and gradually expands to a 100-µm ID tube as it exits through the side of the hohlraum. The tube then attaches to a 1.5-cc reservoir, which is prefilled with 2.2 bars of D_2. The temperature of the fill reservoir can be independently controlled. With the capsule chilled to slightly above the triple point of D_2, the fill reservoir temperature is increased so that the D_2 vapor pressure in the fill reservoir exceeds the vapor pressure of D_2 liquid at the temperature of the capsule. Liquid D_2 then condenses in the capsule until the vapor pressure of the liquid in the capsule equilibrates with the reservoir pressure. Further increasing the reservoir temperature will cause additional D_2 to condense inside the capsule. Thus, the D_2 fill can be controlled by setting the temperature of the fill reservoir. Measurements of the liquid D_2 fill vs reservoir temperature are shown in Fig. 3.

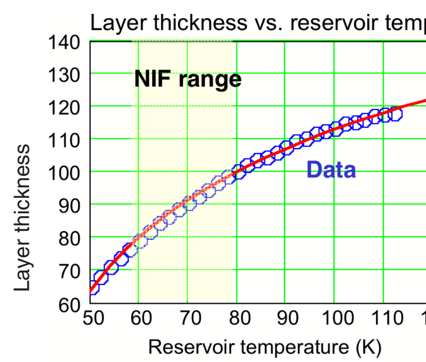

Fig. 3. Estimated layer thickness versus reservoir temperature.

We have developed a reproducible technique for drilling small holes for fuel filling in the capsule and have shown that the fuel layer can be controlled with sufficient accuracy using the self-contained hohlraum target. Future efforts will concentrate on perfecting the attachment of the fill tube to the fill hole, demonstrating controlled filling of DT through a 4-µm ID fill tube, and x-ray characterization of the DT ice layer in a Be shell.

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